Űrcsillagászat – a fantázia és tudomány találkozása

Kiss L. László
MTA Csillagászati és Földtudományi Kutatóközpont
Csillagászati Intézet

Csillagászat és a gyakorlati haszon

- A csillagászat alapkutatás – nem várható azonnali alkalmazás.
- Az a jó kérdésfelvetés, aminek a megválaszolásához technológiát kell fejleszteni.
- 17–18. század:
  - tökéletes optikák
  - földrajzi helymeghatározás
- 20–21. század:
  - tökéletes műszerek
  - számítástechnikai fejlesztések

Global Positioning System (GPS)

Alkalmazott égi mechanika!

Smithsonian National Air and Space Museum

Wifi: Legyen Ön is milliomos csillagász!

JOSA LETTERS

Image sharpness, Fourier optics, and redundant-spacing interferometry

J. P. Hamaker, J. D. O'Sullivan, and J. E. Noordam

Radio Observatory, Dwingeloo, The Netherlands

(Received 2 February 1977; revision received 7 May 1977)

We give a simple proof of the image sharpness criterion S_1 introduced by Muller and Buffington. A close connection with interferometric techniques for diffraction-limited imaging is pointed out. The method of our proof provides indications on the limited validity of several other sharpness criteria.

In a recent paper, Muller and Buffington[1] discuss a number of criteria that can be used for the real-time dynamic cancellation of phase errors introduced by atmospheric turbulence. In particular, they show that maximization of

$$S_1 = \iint I^2(\mathbf{x})\, d\mathbf{x}\,, \qquad (1)$$

where $\mathbf{x}$ is the image coordinate vector, produces an error-free diffraction-limited image. The proof they offer for this assertion is cumbersome and fails to provide any insight into the physical meaning of the optimization process. We offer the following simple and illuminating proof.

According to a basic relation in the theory of Fourier optics,[2] $I(\mathbf{x})$ is (apart from scale factors which are irrelevant in the present context) the Fourier transform (FT) of the product of the mutual coherence or visibility function $V(\mathbf{u})$ in the entrance pupil and the optical transfer function $T(\mathbf{u})$:

$$I(\mathbf{x}) \xleftrightarrow{\mathrm{FT}} V(\mathbf{u})\, T(\mathbf{u})\,. \qquad (2)$$

T is the autocorrelation function of the pupil function $P(\mathbf{u})$:

$$T(\mathbf{u}) = \iint P(\mathbf{w})\, P^*(\mathbf{w}+\mathbf{u})\, d\mathbf{w}\,. \qquad (3)$$

According to Parseval's theorem, then

$$S_1 = \iint I^2(\mathbf{x})\, d\mathbf{x} = \iint |V(\mathbf{u})|^2\, |T(\mathbf{u})|^2\, d\mathbf{u}\,. \qquad (4)$$

$$\epsilon(\mathbf{w}) - \epsilon(\mathbf{w}+\mathbf{u}) = \Phi(\mathbf{u}) \quad \text{independent of } \mathbf{w}\,. \qquad (8)$$

By expanding ϵ in a Taylor series,

$$\epsilon = a + \mathbf{b}\cdot\mathbf{u} + \mathbf{u}^T C\mathbf{u} + \cdots\,; \qquad (9)$$

and substituting, one recognizes that no terms beyond the linear one can exist. Thus,

$$\epsilon(\mathbf{a}) = a + \mathbf{b}\cdot\mathbf{u}\,. \qquad (10)$$

The constant a is of no consequence. The tilt $\mathbf{b}$ corresponds to a shift of the image. Apart from this shift, maximizing S_1 leads to a perfect diffraction-limited image.

Before discussing an interesting parallel with radio-astronomical imaging techniques, we must at this point briefly digress on the concept of redundancy as it is familiar to radio practitioners. As Eq. (2) above indicates, a single measurement of the visibility function for each separation $\mathbf{u}$ present in the pupil would suffice to construct the image. This is indeed the standard practice in radio aperture synthesis. Its basic measuring device is the correlating interferometer, consisting of two antennas and an electronic correlator. Once the visibility values have been obtained, the image can be constructed with an optical transfer function $T(\mathbf{u})$ which can be arbitrarily specified. Radio interferometer arrays are therefore preferably laid out with "minimum redundancy," i.e., as many different separations as possible are realized with a given number of antennas. On the other hand, the presence of redundant element

Wifi: Legyen Ön is milliomos csillagász!

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Wifi: Legyen Ön is milliomos csillagász!

Űrfotometria: mire jó az?

Nagyságrendi ugrások a fényességmérés ***relatív pontosságában***

- Új fizika!
- 100%: Mirák, (szuper)nóvák
- 1–10%: Geometriai és fizikai (pulzáló, eruptív és kataklizmikus) változócsillagok
- 0,1%: Fedési exobolygók – forró jupiterek
- 0,0001–0,01%: Nap típusú csillagrezgések, exoholdak, exoföldek, ???

Űrfotometria: mire jó az?

Az űrbéli mérések célja

- A földi légkör zavaró hatásaitól mentes adatgyűjtés
- A nappalok és éjszakák váltakozásaitól mentes mérések
- Fotonzaj-limitált adatok (0,1% – 1 millió foton)
- Kis távcső – fényes csillag!

Exobolygók: 51 Pegasi (1995)

ARTICLES

A Jupiter-mass companion to a solar-type star

Michel Mayor & Didier Queloz

Geneva Observatory, 51 Chemin des Maillettes, CH-1290 Sauverny, Switzerland

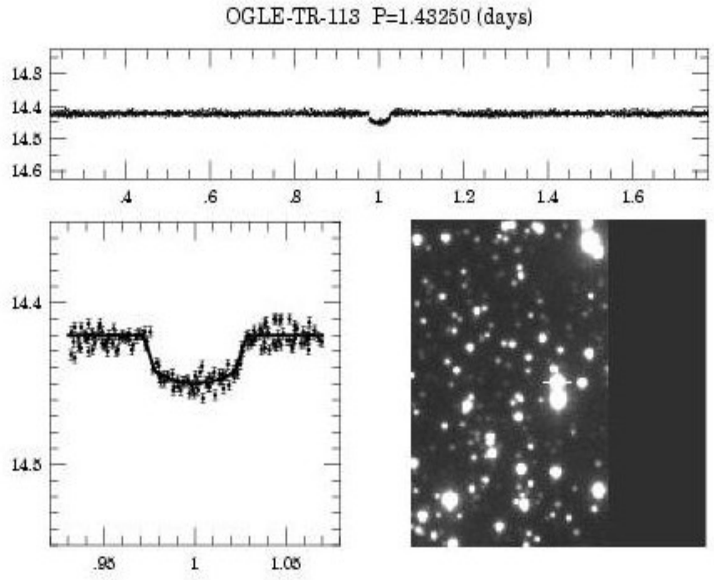
The presence of a Jupiter-mass companion to the star 51 Pegasi is inferred from observations of periodic variations in the star's radial velocity. The companion lies only about eight million kilometres from the star, which would be well inside the orbit of Mercury in our Solar System. This object might be a gas-giant planet that has migrated to this location through orbital evolution, or from the radiative stripping of a brown dwarf.

NATURE · VOL 378 · 23 NOVEMBER 1995 **355**

Más csillagok napfogyatkozásai

Fedési exobolygók: a bolygó elhalad a csillag előtt, és kitakarja. Ebből megállapítható, kiszámítható, detektálható:

- a valós méret (a csillagsugár arányában)
- a sűrűség
- a bolygó szerkezete!
- a bolygólégkör színképe
- a visszavert fény
- a bolygólégkör szerkezete
- a csillag légkörének szerkezete



A Kepler-űrtávcső

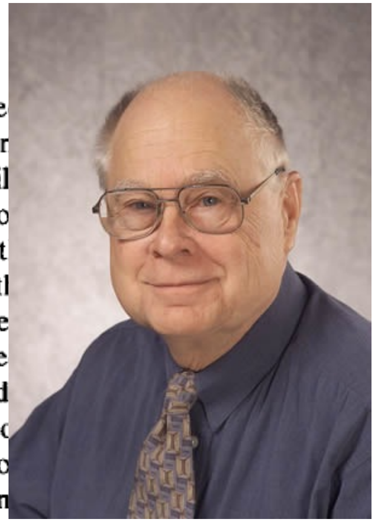
ICARUS 58, 121–134 (1984)

The Photometric Method of Detecting Other Planetary Systems

WILLIAM J. BORUCKI AND AUDREY L. SUMMERS

Theoretical and Planetary Studies Branch, NASA–Ames Research Center, Moffett Field, California 94035

Received August 10, 1983; revised January 18, 1984



The photometric method detects planets orbiting other stars by searching for the re light flux or the change in the color of the stellar flux that occurs when a planet trar transit by Jupiter or Saturn would reduce the stellar flux by approximately 1% whil Uranus or Neptune would reduce the stellar flux by 0.1%. A highly characteristic colo an amplitude approximately 0.1 of that for the flux reduction would also accompany t could be used to verify that the source of the flux reduction was a planetary transit ratl other phenomenon. Although the precision required to detect major planets is alre with state-of-the-art photometers, the detection of terrestrial-sized planets would re sion substantially greater than the state-of-the-art and a spaceborne platform to avoid variations in sky transparency and scintillation. Because the probability is so small c planetary transit during a single observation of a randomly chosen star, the search pro designed to continuously monitor hundreds or thousands of stars. The most promisin to search for large planets with a photometric system that has a single-measurement precision of 0.1%. If it is assumed that large planets will have long-period orbits, and that each star has an average of one large planet, then approximately 10^4 stars must be monitored continuously. To monitor such a large groups of stars simultaneously while maintaining the required photometric precision, a detector array coupled by a fiber-optic bundle to the focal plane of a moderate aperture (≈1 m), wide field of view (≈50°) telescope is required. Based on the stated assumptions, a detection rate of one planet per year of observation appears possible.

A Kepler-űrtávcső

A Kepler célja Föld méretű, lakható bolygók felfedezése a fedési módszerrel.

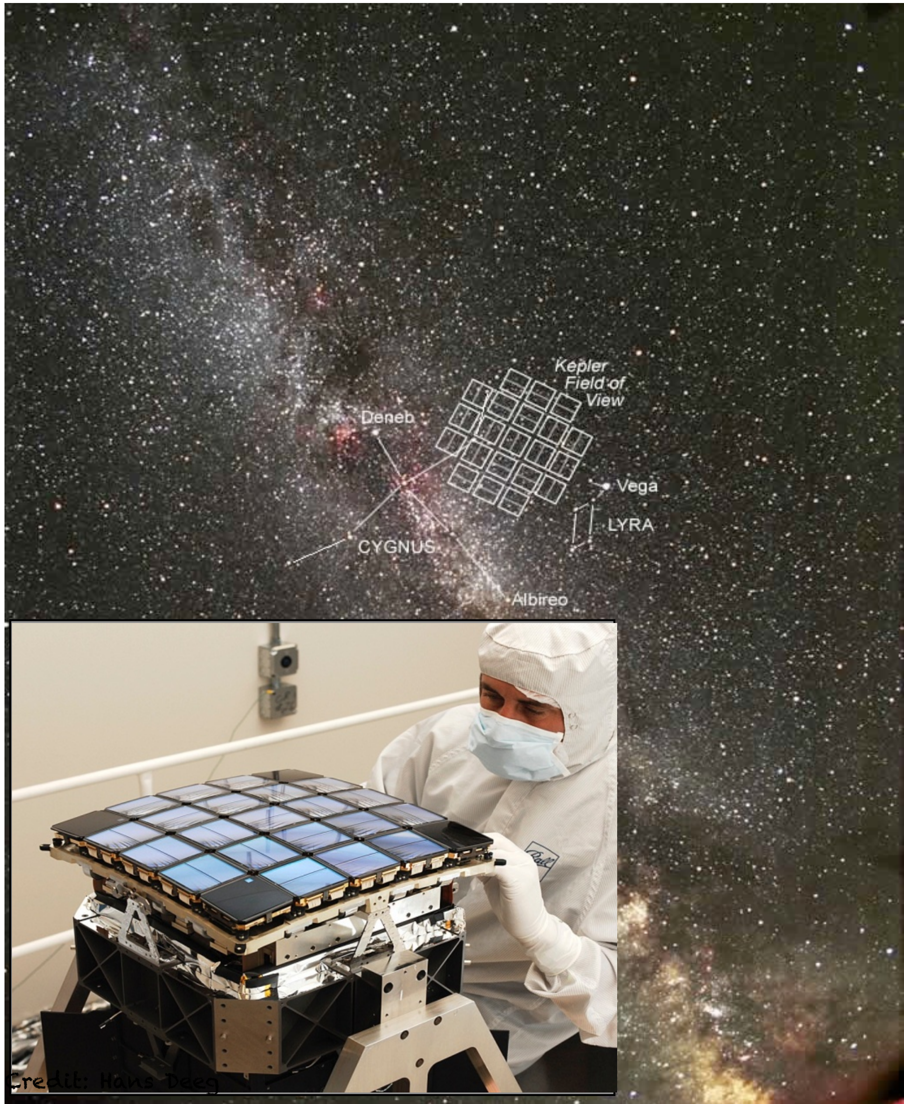
Szimultán észlelt több mint 150 ezer csillagot (2009–2013).

95 cm-es belépő nyílású Schmidt-távcső, látómezeje mintegy 100 négyzetfok, 42 CCD-ből álló mozaikkal

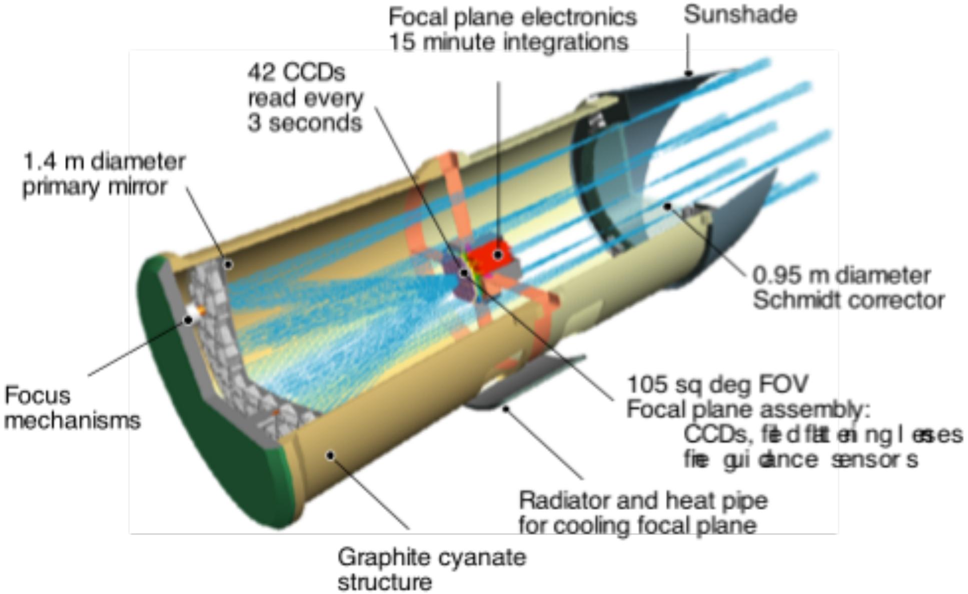
Fotometriai pontosság:

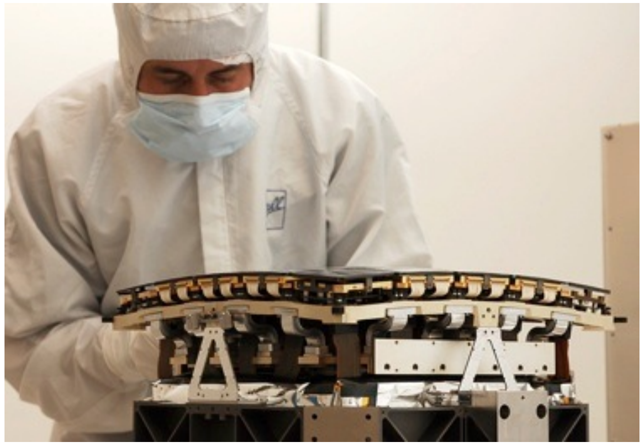
A zaj < 20 ppm 6,5 órányi mérés után egy 12 magn. Nap típusú csillagra

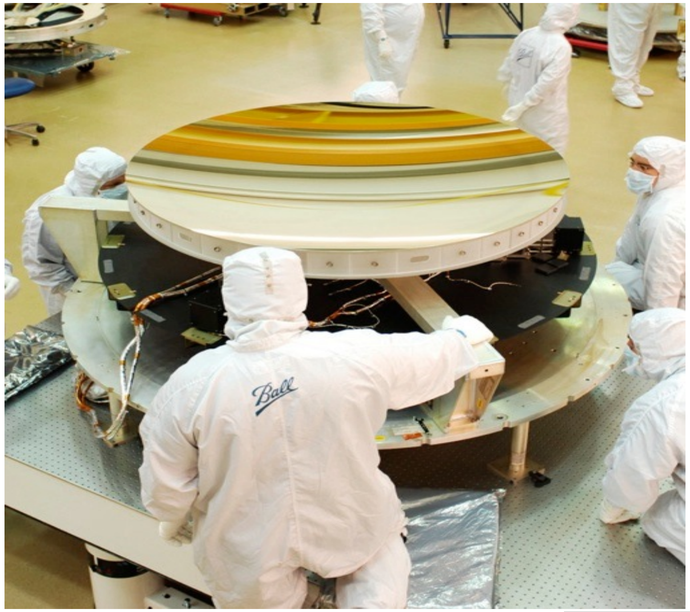
=> 4-szigma detektálás egy exoföld tranzitja esetén.



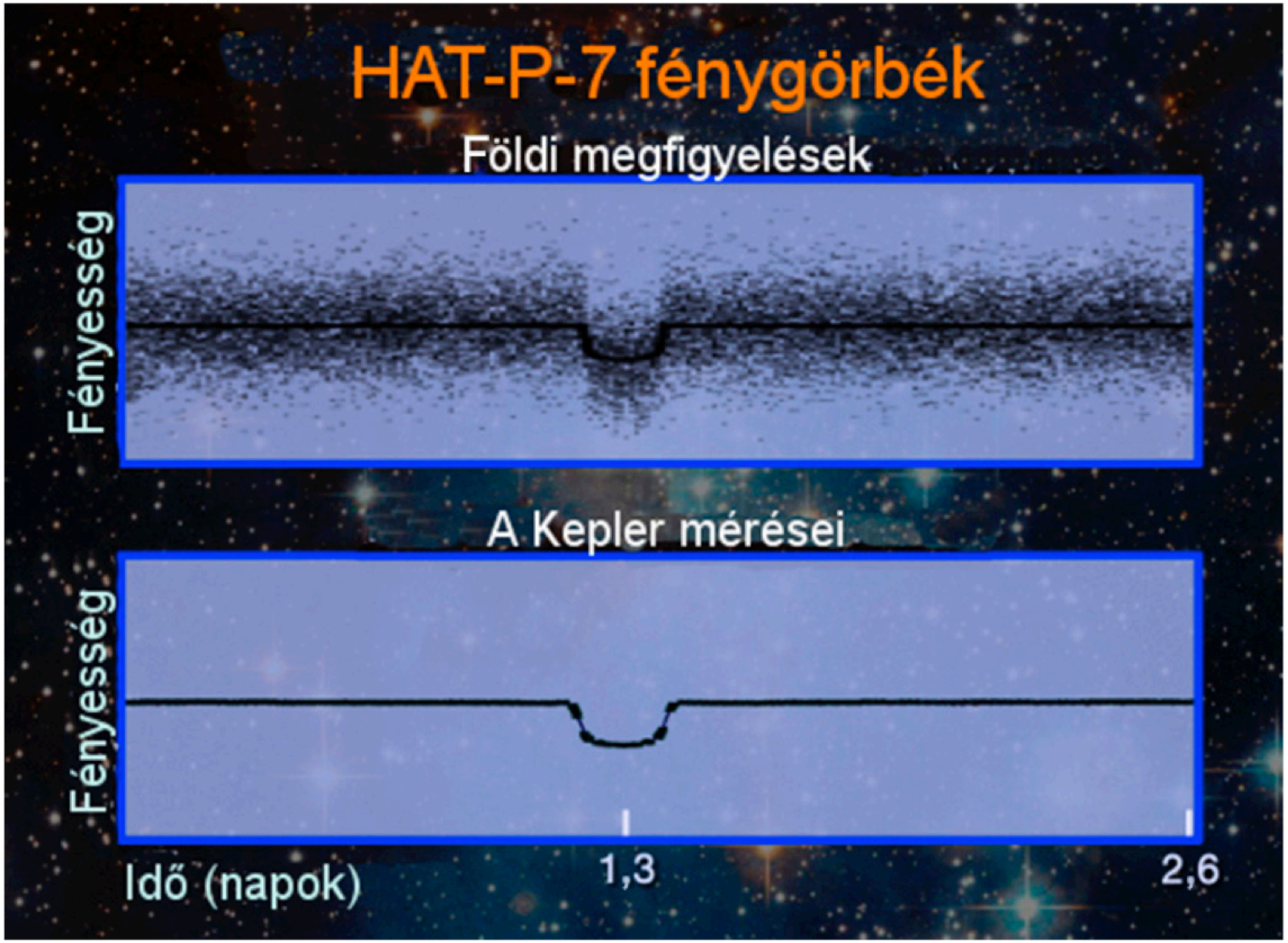
A Kepler-űrtávcső



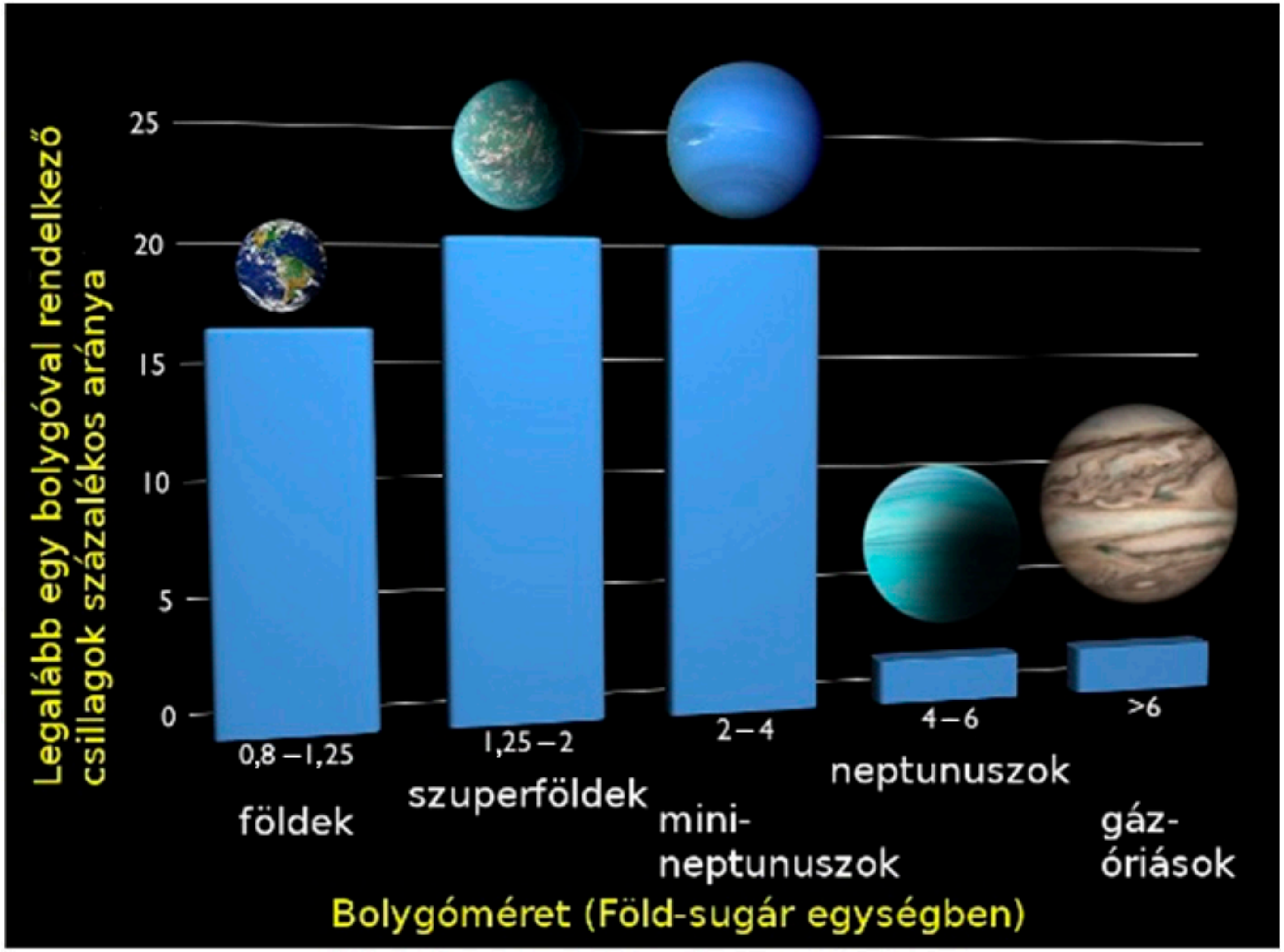




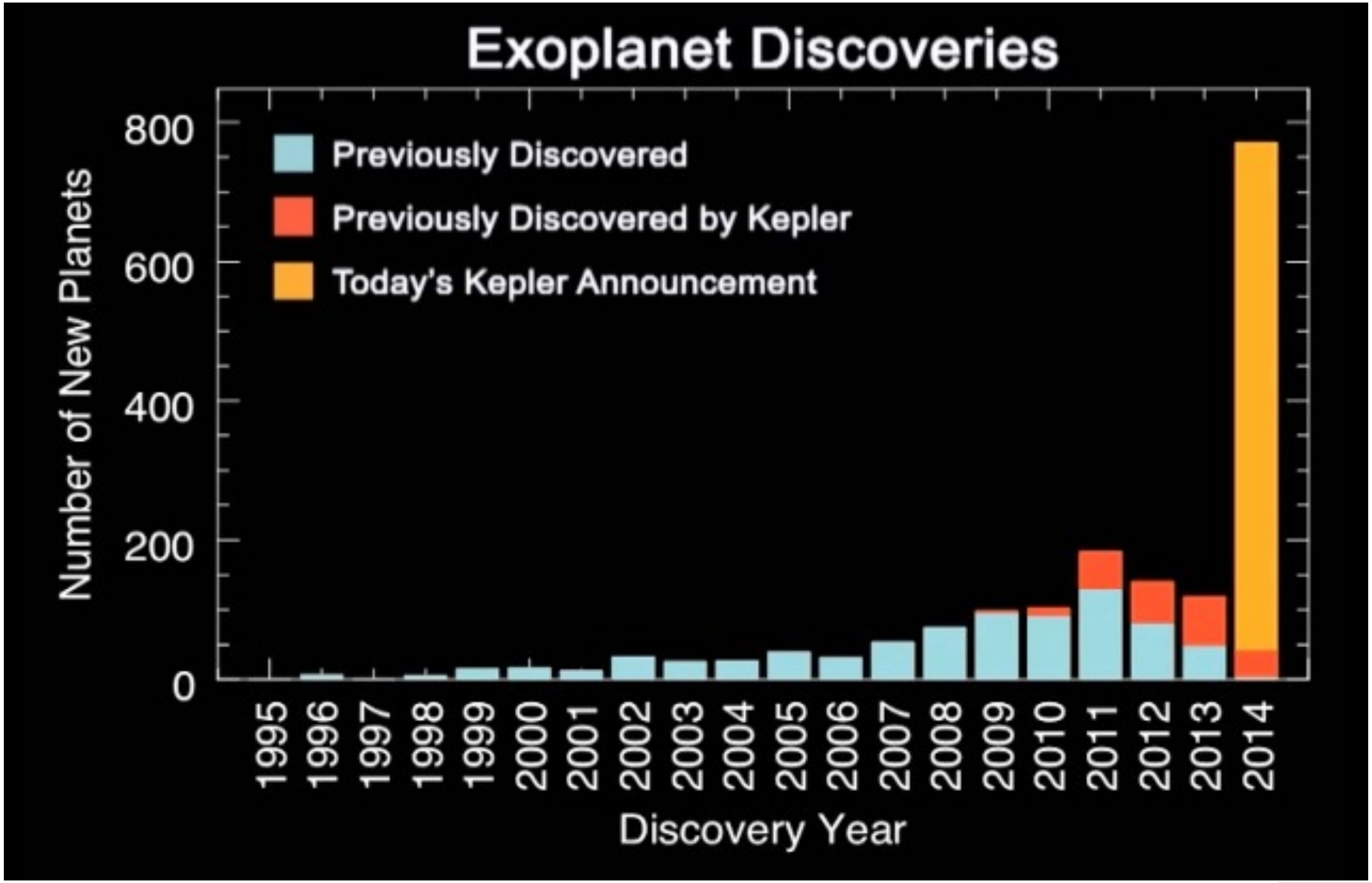
A Kepler-űrtávcső



A rövidperiódusú bolygók gyakorisága



2014. február: 715 új bolygó



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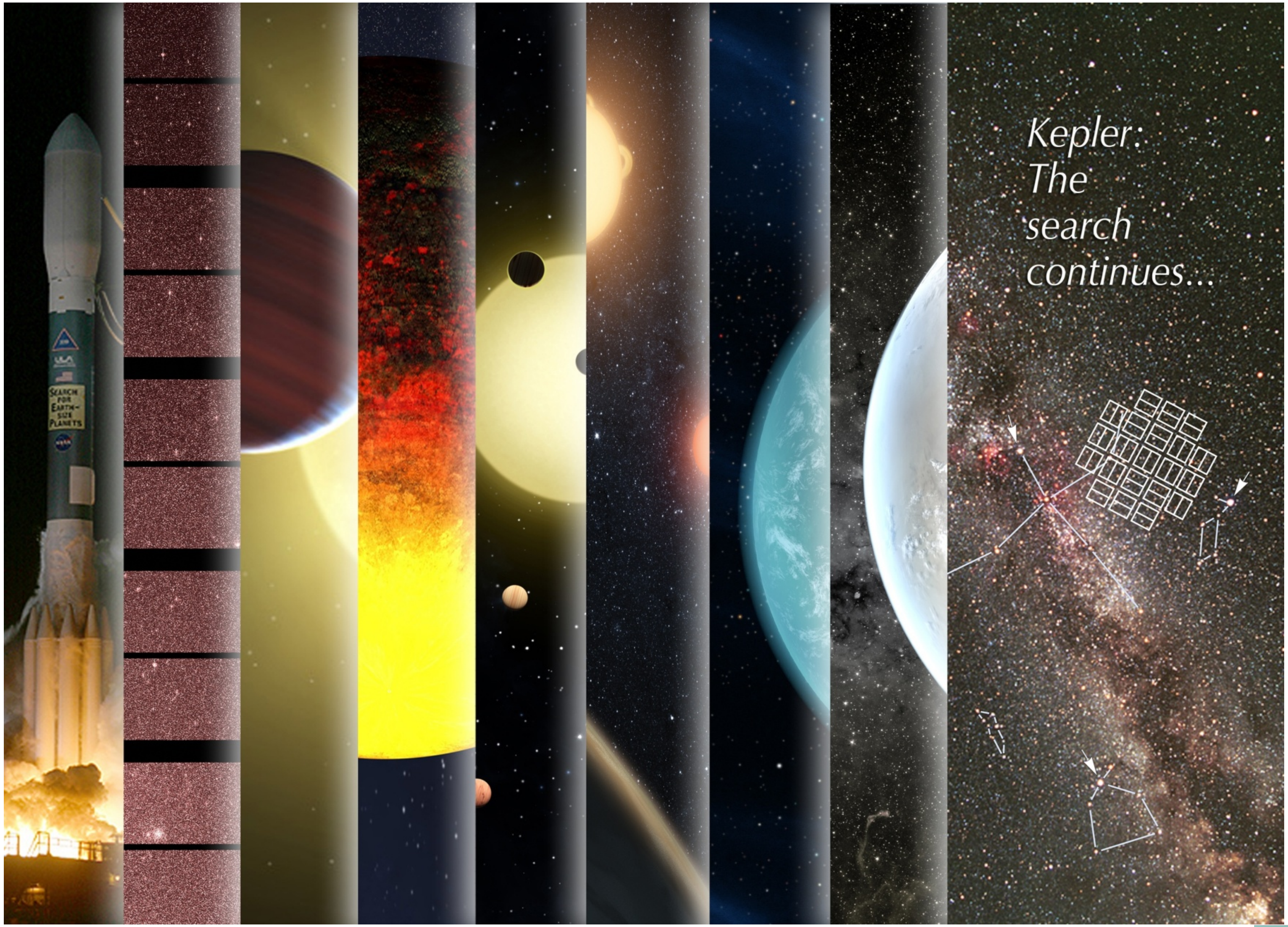

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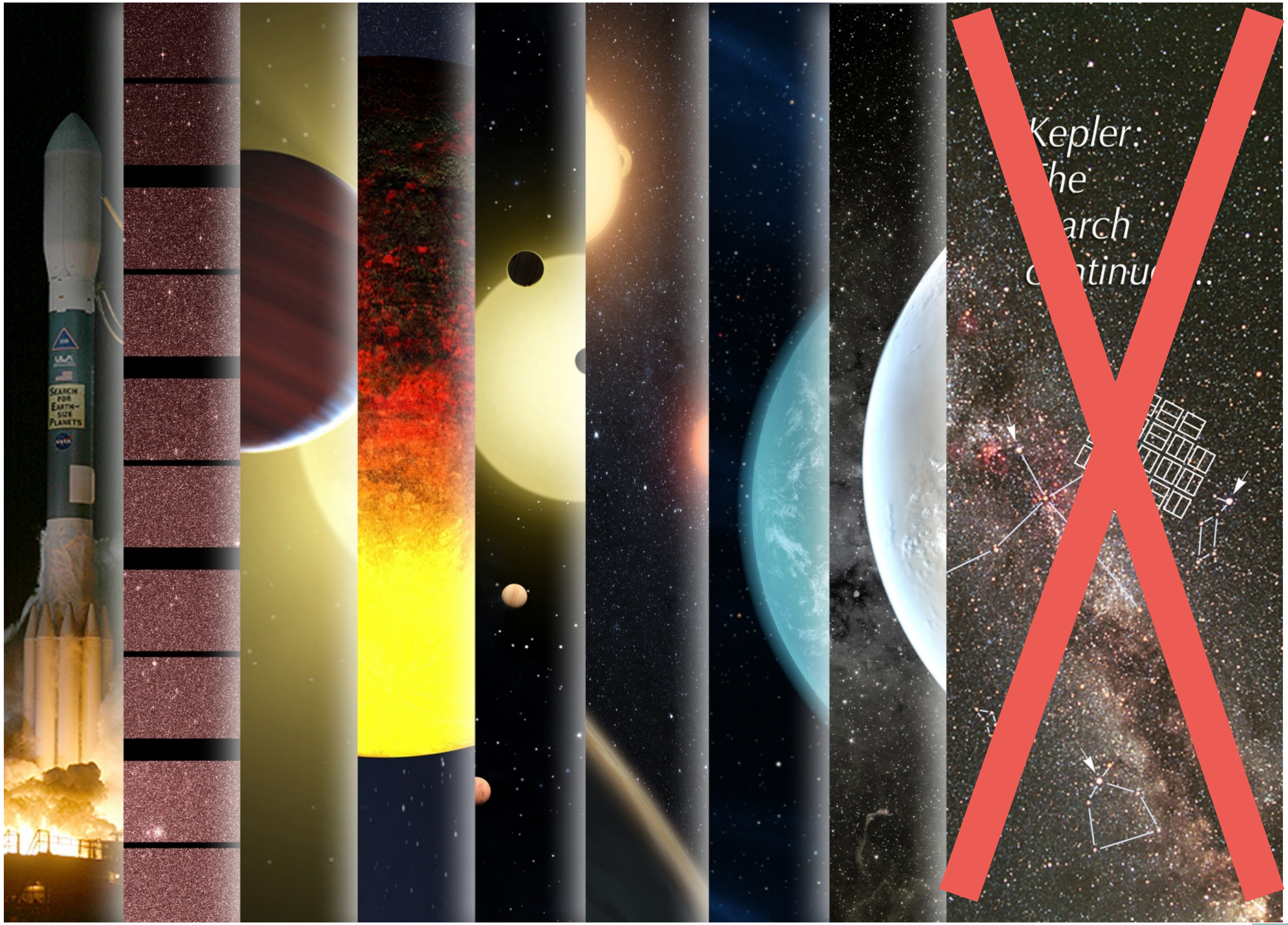
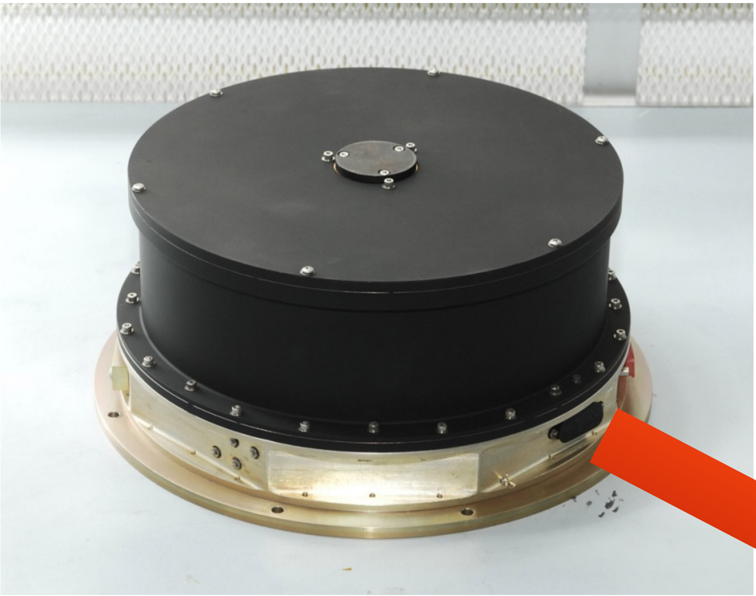
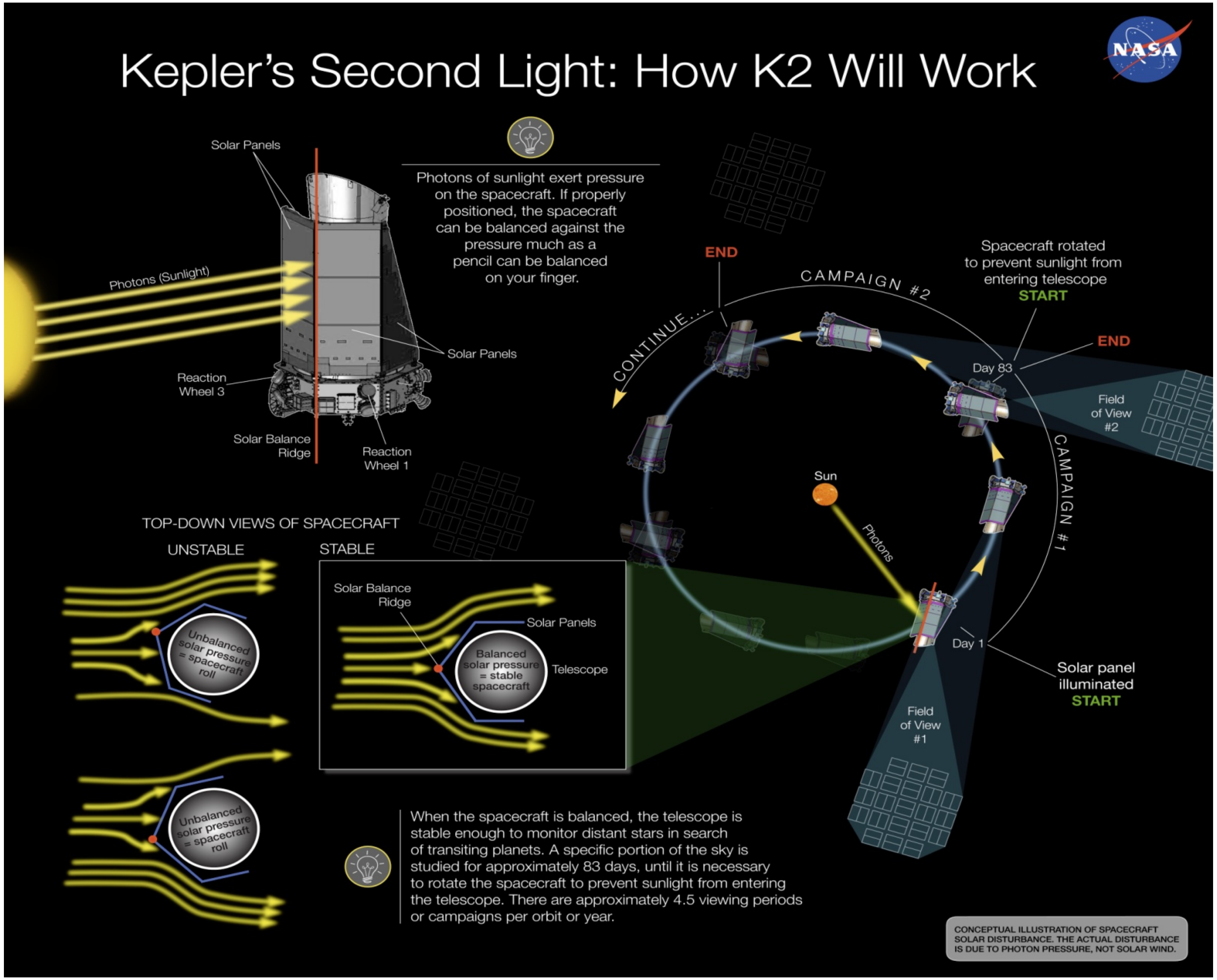


2013. május: A 2. elromlott lendkerék

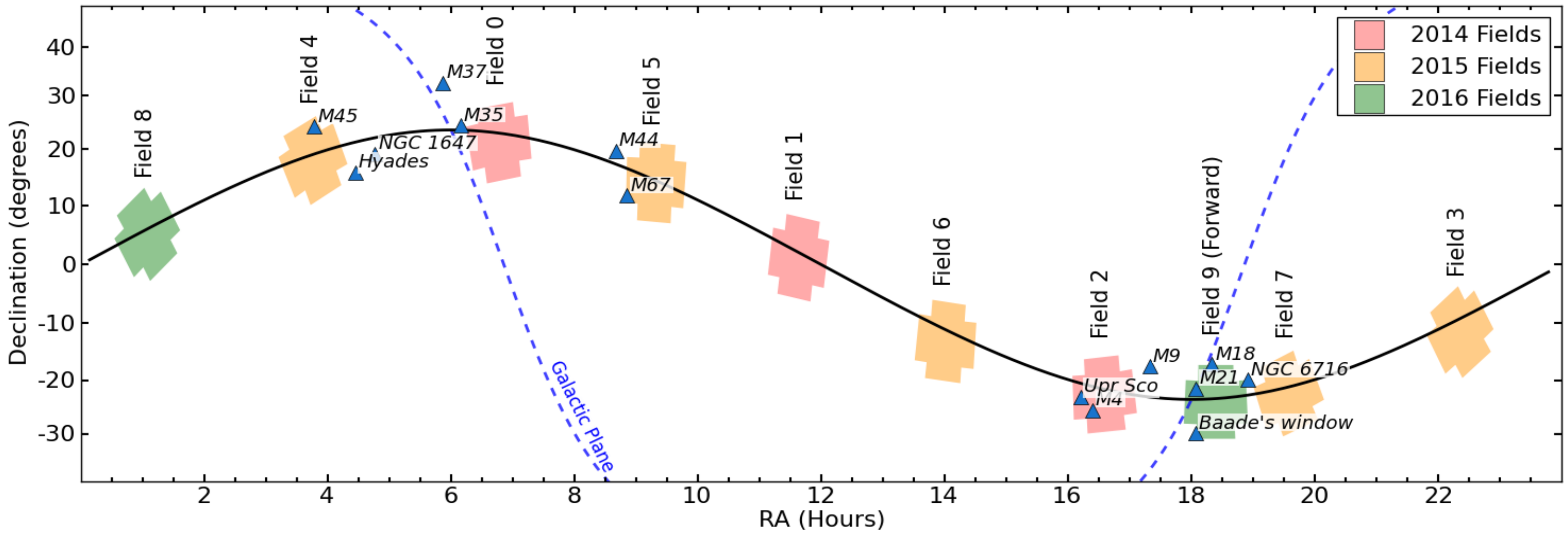


A K2-misszió


Kepler's Second Light: How K2 Will Work
NASA
Solar Panels
Photons (Sunlight)
Photons of sunlight exert pressure on the spacecraft. If properly positioned, the spacecraft can be balanced against the pressure much as a pencil can be balanced on your finger.
Solar Panels
Reaction Wheel 3
Solar Balance Ridge
Reaction Wheel 1
TOP-DOWN VIEWS OF SPACECRAFT
UNSTABLE
STABLE
Unbalanced solar pressure = spacecraft roll
Solar Balance Ridge
Solar Panels
Balanced solar pressure = stable spacecraft
Telescope
Unbalanced solar pressure = spacecraft roll
When the spacecraft is balanced, the telescope is stable enough to monitor distant stars in search of transiting planets. A specific portion of the sky is studied for approximately 83 days, until it is necessary to rotate the spacecraft to prevent sunlight from entering the telescope. There are approximately 4.5 viewing periods or campaigns per orbit or year.
END
CAMPAIGN #2
CONTINUE...
Spacecraft rotated to prevent sunlight from entering telescope
START
END
Day 83
Field of View #2
CAMPAIGN #1
Sun
Photons
Day 1
Solar panel illuminated
START
Field of View #1
CONCEPTUAL ILLUSTRATION OF SPACECRAFT SOLAR DISTURBANCE. THE ACTUAL DISTURBANCE IS DUE TO PHOTON PRESSURE, NOT SOLAR WIND.

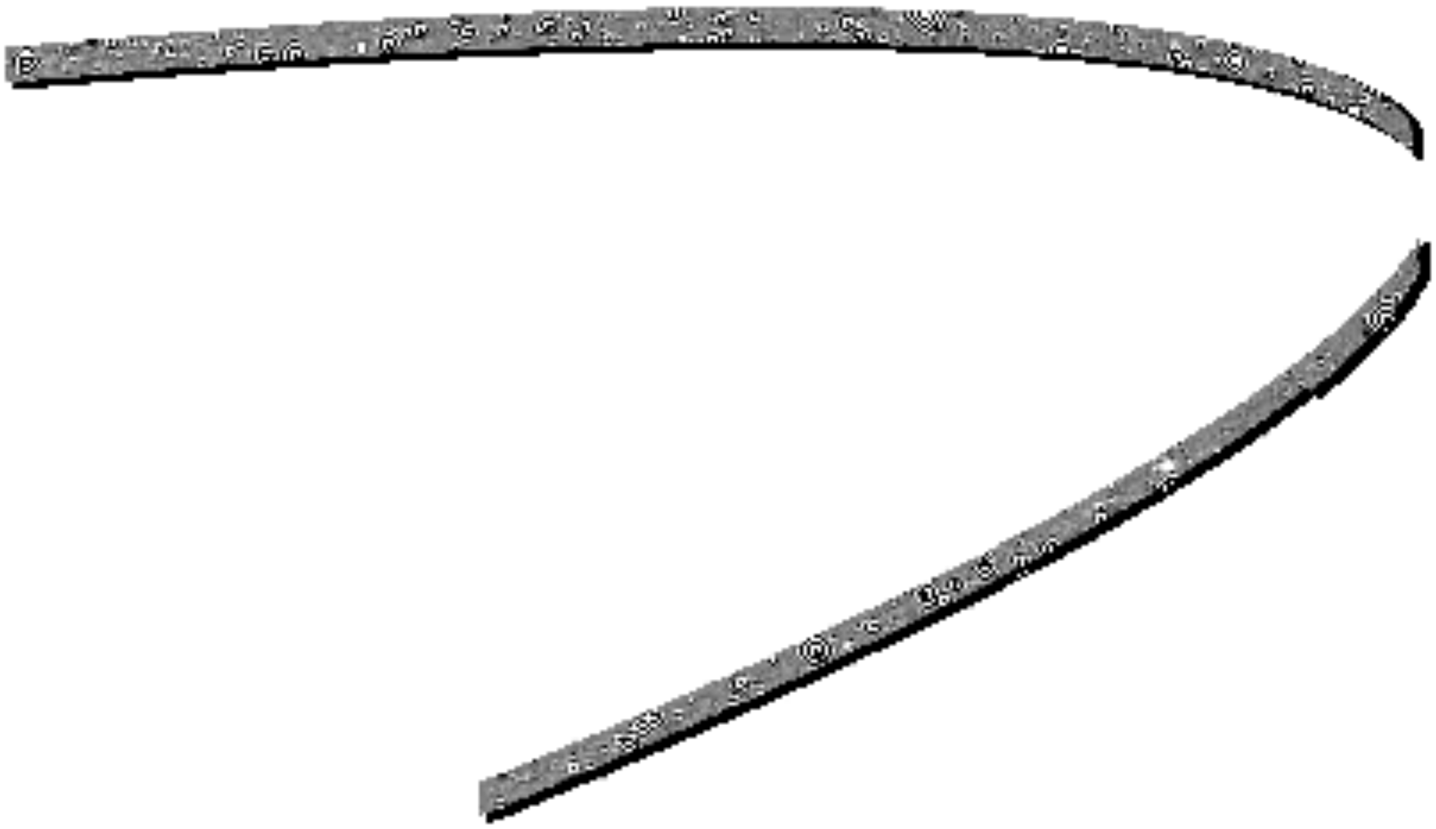
A K2-misszió

K2
Extending Kepler's Power to the Ecliptic



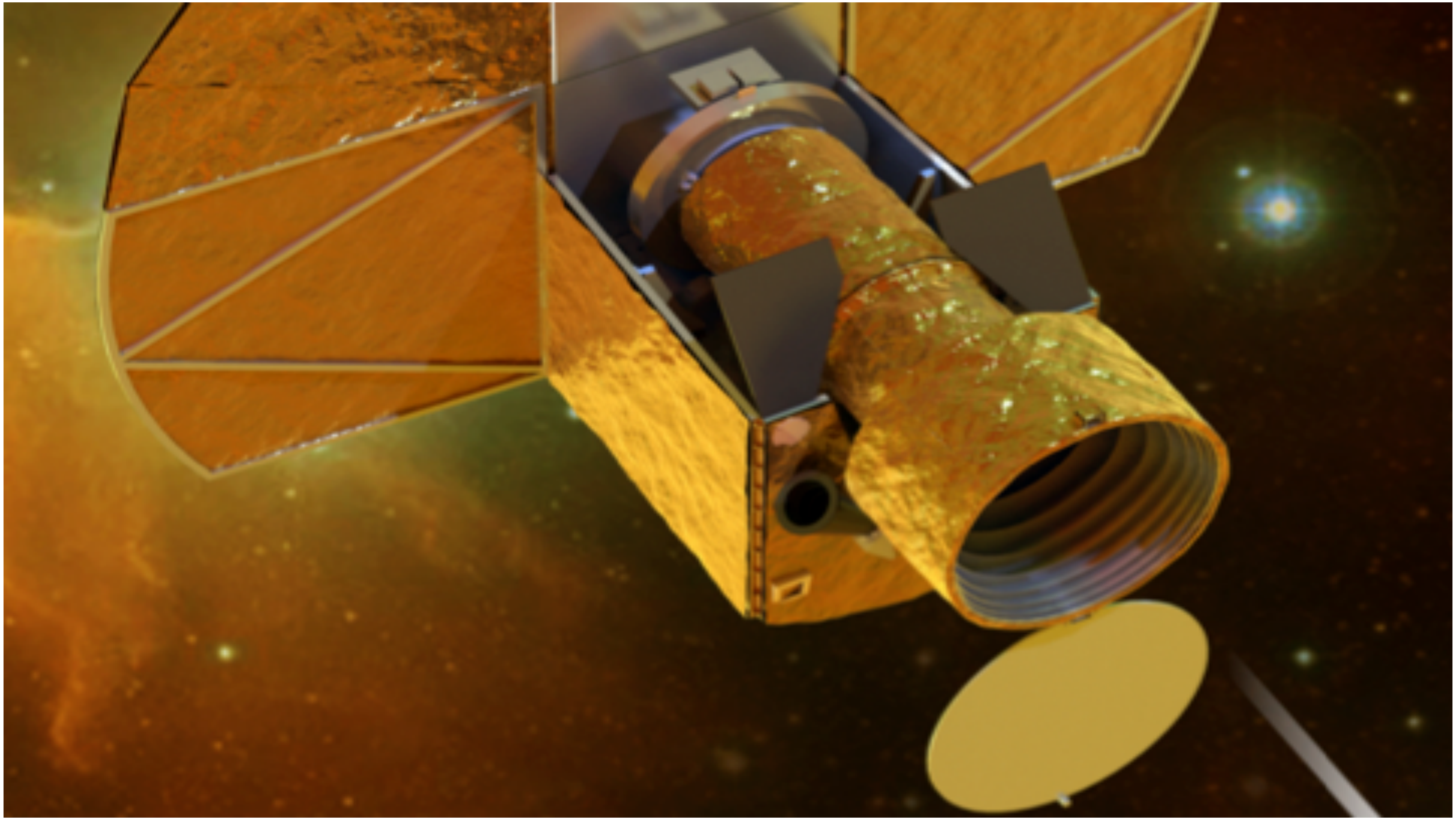
2014 Fields
2015 Fields
2016 Fields
Declination (degrees)
RA (Hours)
Field 8
Field 4
Field 0
Field 5
Field 1
Field 6
Field 2
Field 9 (Forward)
Field 7
Field 3
M45
M37
M35
NGC 1647
Hyades
M44
M67
M9
M18
M21
NGC 6716
Upr Sco
M4
Baade's window
Galactic Plane

2007 JJ43: Neptunuszon túli kisbolygó a Keplerrel!



CHEOPS (2017 – 2020)

CHEOPS (2017 – 2020)



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Advanced Materials in Space

A konzorcium vezetője:
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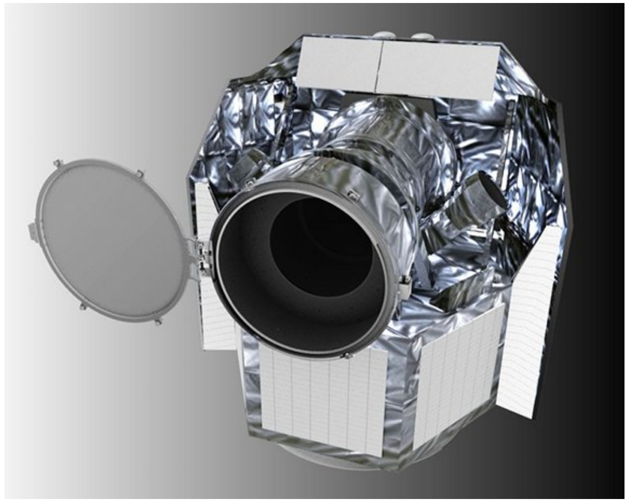
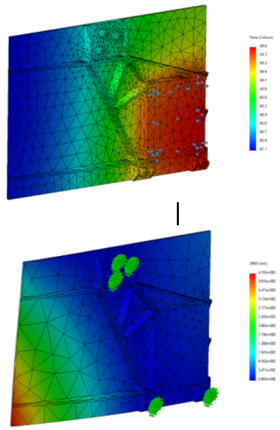
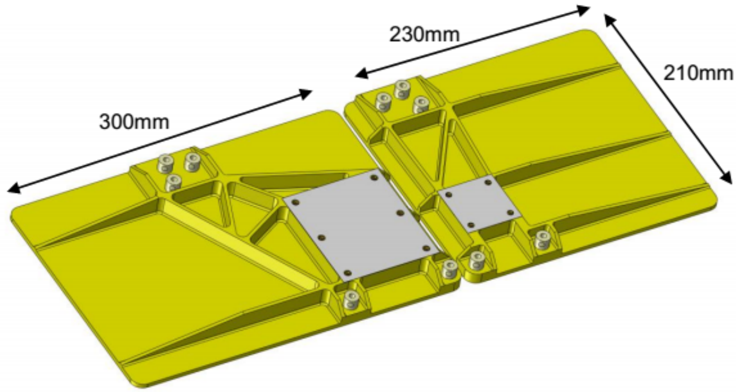
Az Admatis feladatai:
Hűtő radiátorok tervezése és kivitelezése.
Az MTA CSFK feladatai:
Exoholdak

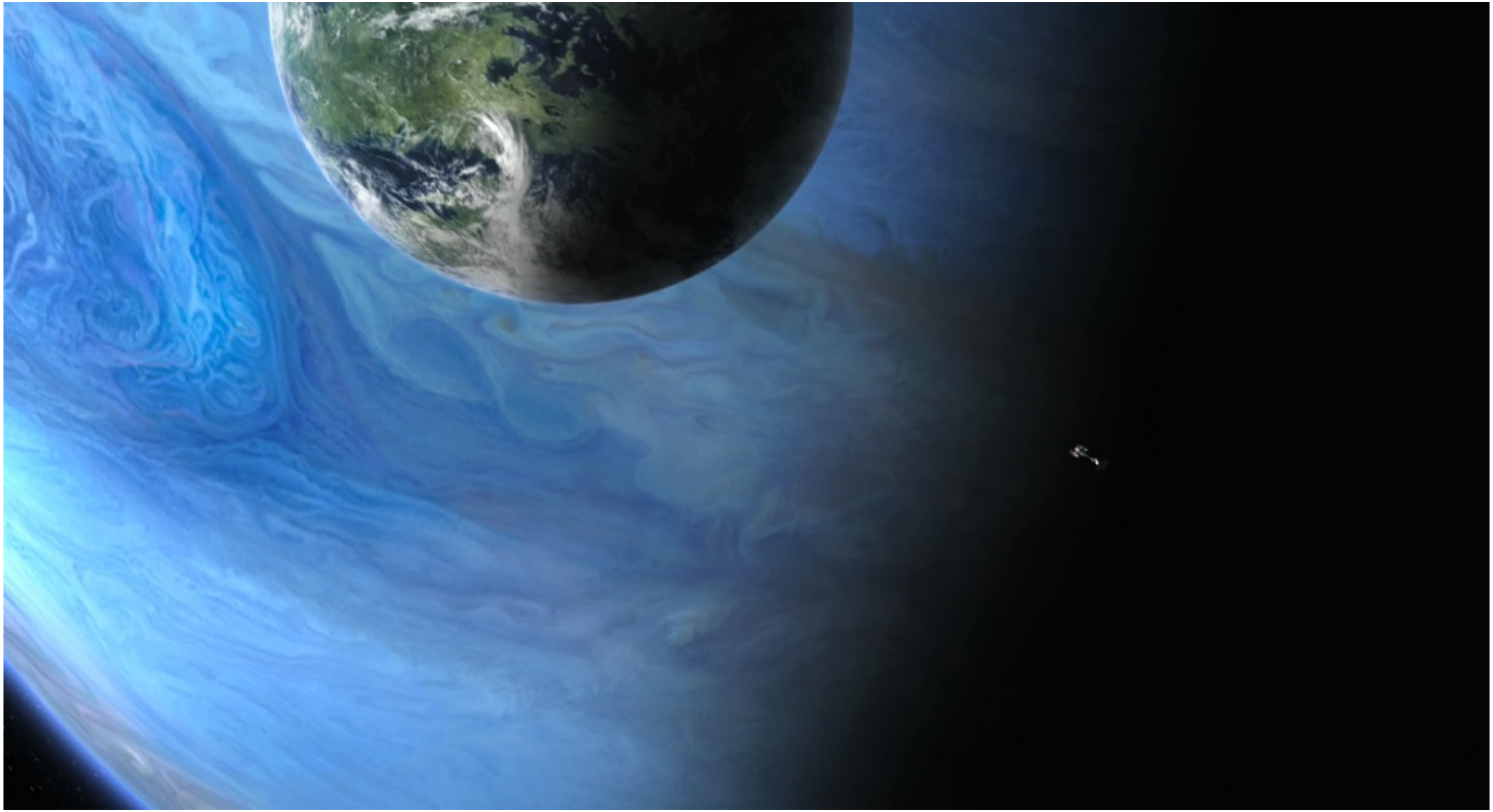






Preliminary design of radiators

Exoholdak



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